

Infrastructures and their invisible carnivalesque

Donncha Kavanagh* and Gianluca Miscione**

UCD School of Business, University College Dublin, Dublin, Ireland.

* donncha.kavanagh@ucd.ie

** gianluca.miscione@ucd.ie

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Abstract

In this paper, we argue that Bitcoin, and cryptocurrencies more generally, is an important and distinctive information infrastructure that warrants substantive study by organizational scholars. The Bitcoin system is briefly described and the particular methodological challenges involved in studying the phenomenon are also discussed. We assert that neither of the two broad conceptualisations of information infrastructures found in the literature—top-down and bottom-up—help us in understanding Bitcoin. Instead, Bitcoin is better understood as a form of game and we draw on the ludology literature and the case material to identify its game dimensions. Bitcoin is a particular type of game, and we introduce the term *Klein Bottle Game* to describe this type of game. A Klein bottle a one-sided, non-orientable surface that has no boundary. We then describe the main features of Klein bottle games. First, they are different from most games in that the boundaries between the game and non-game worlds are not decipherable. Second, we use the term Klein Portal to describe the particular set of practices that link the Klein Bottle Game that is Bitcoin to other infrastructures. Third, we argue that Bitcoin exhibits many of the features of the carnivalesque—hence we speak of the crypto-carnivalesque—in that it is a site where norms and structures are temporarily suspended, conventional authority is contested, and autonomy if favoured over heteronomy. Fourth, Bitcoin is a site of ironic inversion, in that the ideology that drove Bitcoin’s initial development shows signs of now being inverted. We conclude by noting the distinctive

nature of Bitcoin and caution against extending our analysis to other instances of information infrastructures.

Keywords: information infrastructure, ethnography, Bitcoin, carnivalesque, Klein bottle.

Introduction

In this paper, we argue that cryptocurrencies—Bitcoin being the exemplar—are an emerging (information) infrastructure that warrants sustained study by organizational scholars.¹

Cryptocurrencies are significant, not only as a new form of money, but also because they will probably be foundational to digital modes of organizing, and, as an infrastructure, will be taken-for-granted and hence unseen in years to come. We argue that our understanding of infrastructures can be deepened through studying Bitcoin, while, conversely, our understanding of Bitcoin (and even monies more broadly) can be enriched by seeing it as an infrastructure. In particular, we highlight the carnivalesque nature of Bitcoin which we posit is an invisible but crucial aspect of digital infrastructural innovation that is overlooked by conventional approaches to the study of infrastructures.

The paper is structured as follows. In the next section we introduce Bitcoin and the blockchain technology on which it is based. Then, we outline the theoretical frame that informs our research and our methodology. We then introduce the idea that Bitcoin may be understood as a “Klein bottle game”. We explain what this concept means and we describe and illustrate five features of the Klein bottle game that is Bitcoin. We then discuss the wider relevance of the case and conclude by pointing to possible future lines of inquiry.

A brief introduction to Bitcoin

Bitcoin² is easily the best-known and the first widely used form of “digital money” or cryptocurrency. While the first bitcoin transaction only occurred in 2009, it is the culmination of decades of research into cryptography and distributed systems. As Antonopolous (2014) explains, it consists of four key innovations brought together in a unique way:

¹ Throughout this text we use cryptocurrency, digital money and digital currencies as synonyms. These terms refer to native digital currencies, such as bitcoin, and not to the digital version of fiat monies, such as the euro, dollar, pound, etc. We use the term “Bitcoin” to refer to the overall Bitcoin network, while “bitcoin” refers to digital money produced by this network.

² We use the term “Bitcoin” to refer to the overall Bitcoin network, while “bitcoin” refers to digital money produced by this network. For a good history of Bitcoin to date, see Popper (2015), while see Antonopoulos (2014) for a detailed description of how it works.

- A decentralized peer-to-peer network (the bitcoin protocol)
- A public transaction ledger (the blockchain)
- A decentralized mathematical and deterministic currency issuance protocol (distributed mining)
- A decentralized transaction verification system (transaction script)

The seminal contribution to the phenomenon was by the mysterious individual or group known as Satoshi Nakamoto, who published a paper that set out the basis for the “blockchain” on which cryptocurrencies such as Bitcoin and other possible services are based (Nakamoto, 2008). Nakamoto began his paper with an imaginary world populated by trustless individuals, and the problem he addresses is how to enable trustworthy transactions on the Internet—where there is not a fixed and known population—without recourse to a trusted third party such as a state-regulated (or state-supported) bank. His solution is the blockchain, which is a public record or ledger of all transactions maintained by a dispersed and open-ended number of “miners”, who provide computing power to guarantee the ledger’s integrity. The blockchain uses cryptography to create an infrastructure through which transactions are certified without recourse to a trusted third party, such as a bank. Bitcoin is then usable by whoever installs a “wallet” on a digital device, there being no form of identity check at access points. Hence, Bitcoin is a purely digital cryptocurrency that is not directly administered by any constituted organization and is not circumscribed within any consistent jurisdiction.

Bitcoin is built around scarcity (money cannot be infinite) and absence (no guarantor) and, unlike traditional currencies, it is not linked to precious metals, nor to a state (fiat money), nor to credit (banks). Nakamoto’s main architectural innovation is the blockchain which is designed to make it impossible to either double-spend money—which would create immediate infinite inflation—or for a unique central authority to rule.

Nakamoto’s attempt to create a money system without a central authority can be situated at the intersection of diachronic and synchronic issues. Historically, the blockchain is part of a long chain of information technologies that, since the 1960s, have avoided centralization tenaciously, partly as a defense against possible Soviet nuclear attack, and partly in sympathy with the Western liberal culture of the 1960s and 1970s. By eluding consolidated control

points and circumventing the consistency of jurisdictions, cryptocurrencies work to weaken some of the theoretical and political strands of social order derived from states. From a more monetary viewpoint, these views echo Hayek's (1976/1990) argument that money should be denationalized and privatized. Rather than describing the phenomenon further—more detail is readily available on the Internet³—we will now proceed to outline the theoretical frame that informs our research.

Theoretical frame

While the call for papers alludes to different types of infrastructure, our study is confined to Bitcoin which we see as an instantiation of an *information* infrastructure. This particular case is interesting because we are witnessing an infrastructure being put in place, before it becomes blackboxed and invisible. Within the literature, two broad conceptualisations of information infrastructures can be identified: one that sees them as manageable assets, amenable to top-down control and requiring a clear IT governance framework (for instance, Weill and Ross (2004)), while another approach argues that the absolute control of information infrastructures is impossible, that deviation from original intentions and unintended consequences are commonplace in such contexts (for example, Ciborra (2000)), and that it is better to conceptualise these heterogeneous socio-technical objects as complex adaptive systems that require “bottom-up” design and a “polycentric” form of governance (Constantinides and Barrett, 2015). Bitcoin provides a potentially interesting case where these two alternative approaches, and perhaps others, might be investigated. But first we need to clarify that Bitcoin warrants being considered an information infrastructure at all.

To address this issue, we first turn to Star and Ruhleder's (1996) influential conceptualisation of an information infrastructure. Their idea builds on the common understanding of an infrastructure as something that is built and maintained, and which is at once ever-present and ready-to-hand, and yet sinks into the background and becomes completely transparent. They go beyond this understanding by emphasizing that an information infrastructure is a fundamentally relational concept that is always grounded in particular practices; for instance, the water system is a piece of infrastructure for a chef cooking dinner, but it is something quite different for a city water engineer. Hence, the issue for Star and Ruhleder (1996) is as

³ The website <https://historyofbitcoin.org> depicts a timeline of the phenomenon; <https://bitcoin.org/>, originally set up by Nakamoto and Martti Malmi, is a resource that supports the development of Bitcoin; the Bitcoin Foundation (<https://bitcoinfoundation.org>) is an organization dedicated to advancing Bitcoin; Coindesk (<http://www.coindesk.com/>) is a news site specializing in bitcoin and digital currencies, while blockchain.info (<https://blockchain.info/>) presents information from the blockchain, such as pool statistics.

much about *when*—rather than *what*—is an infrastructure. For them, infrastructures are characterized by a number of dimensions.

1. They are “sunk” into other structures, social arrangements and technologies (embeddeness).
2. They do not have to be reinvented with each task (transparency).
3. They reach beyond a single event or one-site practice (scope).
4. They are learned as part of membership of a community of practice.
5. They shape and are shaped by the conventions of a community of practice.
6. They plug into other infrastructures and tools in a standard way.
7. They are built on an installed base.
8. They become visible upon breakdown.

Hence, “an infrastructure *occurs* when local practices are afforded by a larger-scale technology, which can then be used in a natural, ready-to-hand fashion. It becomes transparent as local variations are folded into organizational changes, and becomes an unambiguous home—for somebody” (1996, p. 114, our emphasis). Bowker and Star (1999) also show how such infrastructures are scaffolded by important classification systems, such as the International Classification of Diseases or the Nursing Interventions Classification.

Bitcoin is generally considered a form of money (though some dispute this) and so we will first consider the idea that *money is an information infrastructure*. Money does seem to exhibit all eight characteristics identified by Star and Ruhleder. It is certainly deeply embedded in other social arrangements, structures and technologies (1); it does not have to be reinvented with each task (2); it reaches beyond single events or one-site practices (3); as a technology, it is learned—from an early age—through membership of a community (4); it is performative in that a community’s collective belief that some pieces of paper are “money” is sustained and validated by the practices that inform that belief, while, at the same time, the belief self-referentially enables and sustains these practices (5); it inserts itself into other infrastructures (e.g. an ERP) in a standard way (6); the creation of the euro out of separate currency systems in 1999 is a good example of money being built on an installed base (7); while Greece’s potential exit from the euro system in 2015 is a good example of money, as an infrastructure, only becoming visible upon threat of breakdown (8). Indeed, money is perhaps the example *par excellence* of something that is in plain sight—we see it everywhere

around us—while at the same time it is invisible, in that we routinely do not think about it as a constructed piece of infrastructure. If money is a form of information infrastructure, then so too is digital money, specifically Bitcoin, which is the empirical focus of our study.

To deepen the analysis, we briefly examine how Bitcoin maps on to another influential, if somewhat competing, conceptualisation of an infrastructure, namely Hanseth and Lyytinen's (2010) highly cited definition of an information infrastructure as “a *shared, open* (and unbounded), *heterogeneous*, and *evolving* socio-technical system...consisting of a set of IT capabilities and their user, operations, and design communities” (p. 4, original emphasis). Bitcoin is shared as it is available to anyone with an internet connection. It is open in that anyone can transact in bitcoin, the underlying code is open-source, while the blockchain itself, as a public ledger, can be considered a public good. It is heterogeneous in that it contains different actors, including miners, coders, transactors, regulators, exchanges, as well as different applications and platforms, such as different altcoins (alternatives to bitcoin), sidechains, and is the basis for other infrastructures such as Ethereum and the Lightning network. It is rapidly evolving: initially, personal computers were used to “mine” bitcoin, but because success in mining is linked to computing power, dedicated mining hardware was quickly developed to the point where large mining “farms” have now been built in locations with cheap electricity. Likewise, the constellation of services and applications that sit on the blockchain network is ever-increasing and evolving.⁴ Many have predicted that Bitcoin will die, but even if it does it will almost certainly be replaced by an alternative cryptocurrency embedded in a new variant of the blockchain technology. At the same time, the Bitcoin protocol is essentially the same as originally set out in Nakamoto's original white paper which continues to provide the infrastructure's overarching ideology, structure and standard.

Continuing our initial analysis, it is also worth considering whether Bitcoin is better understood as an information infrastructure or a platform. For Hanseth and Lyytinen (2010), examples of platforms include office software platforms (e.g., MS Office), operating system platforms (e.g., Windows, Linux), application frameworks like ERP (e.g., SAP, Oracle), or application development platforms (e.g., Service Oriented Architecture). They distinguish platforms from information infrastructures in that the organising principle of the former is “direct” composition, while the latter are recursively organized—meaning they return “onto”

⁴ A recent report by the World Economic Forum (2016) indicates that 80% of banks are predicted to initiate blockchain projects in 2017, that over 2500 patents relating to the blockchain have been lodged since 2012, and that venture capitalists have invested over \$1.4 billion in blockchain-related businesses over the last three years.

themselves through being composed of similar elements—and they are at once the outcome and condition of design action. While control is centralized in platforms, it is distributed and dynamically negotiated in information infrastructures. Based on this distinction, Bitcoin—and the blockchain technology in which it is embedded—is better understood as an information infrastructure rather than a platform. Bitcoin is a quintessentially distributed system, designed to resist centralisation—though some centralisation has emerged in mining pools, for example—while changes to the open source software must be dynamically negotiated among the user community. Bitcoin is also recursively organised, though autopoietic organisation might be a better-known term. Maturana and Varela (1973/1980) define an autopoietic machine as:

a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network. (p. 78)

An autopoietic machine (or system) may be usefully compared with an *allopoeitic* system, such as a bicycle factory, which makes organized structures (bicycles) each one being something *other* than itself (the factory). In contrast, Bitcoin is an *autopoietic* system in that it works to recreate and extend itself. For instance, the bitcoin generated by the Bitcoin system (machine) are at the same time a rewarding scheme for miners and a currency for other users. Also, the essence of the blockchain technology is that it ensures that each copy of the blockchain is identical, no matter how many copies are created and how big the network becomes. Variants of the blockchain (known as forks) are quickly weeded out through a proof-of-work process that authenticates one, and only one, blockchain.

Before progressing with our analysis, we need to say something about the methodological issues involved in studying information infrastructures and the particular approach we took and the choices we made in this research.

Studying Information Infrastructures

Building on her earlier work with Ruhleder, Star (1999) considered some of the methodological challenges facing those interested in studying infrastructures. Her work is situated within the broader tradition of Actor-Network Theory (ANT), which is—as its founders repeatedly claim—a methodological lens to study the social and the technical to understand how particular (sociomaterial) orders come to be. It is primarily a method of inquiry in the ethnomethodological tradition, although it distinguishes itself from

ethnomethodology by trying not to privilege humans, consciousness or pre-existing structures, either methodologically or theoretically. To begin, she cautions against the traditional ethnographic focus on talk, community, identity and group processes, mediated by information technology. Instead, she argues that any study of infrastructure requires that attention be paid to the most diverse and mundane things, like plugs, standards, bureaucratic forms, or debates about issues like domain names and exchange protocols. These may be boring, but they are nonetheless tremendously important if we want to study that which is embedded. She poses pertinent methodological questions: How does one study action at a distance? When is an infrastructure finished? How would we know that? What values and ethical principles do we inscribe in information environments? She suggests that paradoxes should not be overlooked, but rather should be used as entry points to develop the empirical work. And if infrastructure is a fundamentally relational concept, then it only becomes real in relation to organized practices and hence these practices should become central to any study. In particular, Star foregrounds questions of scale, given that infrastructures are routinely constituted by groups distributed geographically and temporally, often involving hundreds of people, large quantities of materiel and precious few self-contained ethnographic sites. Such issues probably require new methods, and indeed the absence of these might help explain why Bitcoin and cryptocurrencies have received such scant attention from information systems scholars thus far.

Previous research experience on information infrastructures and monies had given us a tacit but clear understanding of the usual strengths and limitations of the qualitative researcher's toolkit. Being aware of the challenges involved in studying digital monies, we approached this study in a somewhat novel way. While Star warns of the inherent limitations of focusing on a community as a proxy for studying a whole infrastructure, we decided to create a community of interest *about* this infrastructure so to be able to cover and discuss more aspects than we could on ourselves, and consider the most diverse views. This team building exercise was started around a small and simple research project intercepting the *zeitgeist* of its time: a two-pager written in the aftermath of the second Greek crisis, in early 2013, that proposed comparing emerging currencies, especially digital, at a time when the Euro seemed to be cracking at its edges. Creating a community around this research interest is not something that can be exhaustively described here. However, the focus was always on understanding the emerging phenomenon of cryptocurrencies through engaging with the practices and practitioners involved. In this sense, we were informed by some of the tenets of

grounded theory (Glaser and Strauss, 1968) in that we tried not to impose prior theoretical frames onto the phenomenon, but were more interested in the interpretations, practices and encoded values of different actors within Bitcoin. To this end, we collected and read a large number of related documents, academic works, contributions to seminars and conferences, and we also continually trawled through and extracted from specialized press and online fora. Concretely, from January 2013 to the present, we systematically read, shared and discussed Bitcoin blogs and forums, online videos, mainstream news, Wikipedia and academic articles and books about Bitcoin and the blockchain, as well as dedicated sites such as bitcoin.org and coindesk.com, news feeds like cryptocoinsnews.com, and numerous websites of organizations and businesses operating in the bitcoin space. Beyond our mailing list and shared file repository, we ran a one-day conference on “gaming money” in May 2015 (63 registered participants, mostly academics, plus 90 online and 140 views of online videorecordings) and a “World Café” in April 2016 on the theme of “translating the blockchain” (35 participants, mainly from industry). We also set up a website (at around 1,000 visitors per month) and a twitter account with its own bot (stably above 50,000 impressions per month). We collected and reviewed the original “white papers” that documented the technical basis for the main cryptocurrencies including Bitcoin, Ripple, Ethereum, and eighteen other altcoins. Over the years, our mailing list and shared file repository emerged as instruments for updating and sensemaking about digital monies among up to eighty people from very different walks of life and expertise (academics from disparate disciplines and continents, practitioners, programmers, activists, students). A number of this group’s members have been directly active in the Bitcoin environment, and thus might be considered participant observers. This is important because, unlike other phenomena of interest to social scientists, which may have an online dimension, the core activities of cryptocurrencies actually happen online. The digital environment is where the action happens. Indeed, in understanding infrastructures as they happen, we have been helped by the fact that crucial Bitcoin matters are publicly discussed online. This is for two main reasons: first, free and open source software matters are by definition discussed openly and publicly via digital means; and, second, cryptocurrencies have not yet become part of common praxes and so they have not slipped into the taken-for-grantedness, typical of established infrastructures. Hence, our longitudinal study is aligned with the actor-network interest in studying how things “come to be”, before becoming black-boxed. This is important in seeking to understand the nature of an information infrastructure, but it seems especially

important that we study the emergence of a new form of money, given how intrinsic money is to social life (Simmel, 1900/2004; Zelizer, 1997; Hart, 2000; Dodd, 2014).

While our observations and data about “Bitcoin in the wild” and related phenomena were certainly not confined to this group, the conversations continuously helped put happenings into perspective, including those disagreements that indicated that different communities were represented within this community and encountering one another. This community of interest worked to effect what Bowker (1994) calls an “infrastructural inversion”—i.e. infrastructures, which tend to be backgrounded, become foregrounded—in the continuous recombination and interpretations of document analyses, technical novelties, breaking news (Bitcoin routinely hit the headlines), court cases, automatic feeds, social media, conference and public presentations, etc. Even if “qualitative research, combined with a historical emphasis on single investigator studies, has never lent itself to ethnography of thousands” (Star, 1999, p. 383), our community-technical arrangement reduced the input to a manageable volume. So, while we cannot claim that our data collection is all-inclusive—due to the sheer scale of the phenomenon—the continuous data selection operated by the diverse news sites we read and the online communities we participated in, refined our interpretations and made them, we feel, reasonably reliable. Conversely, the large amount of longitudinal data, shared in our repository of documents, fed into academic and also public discourse through our presence in specialized gatherings and outlets.

Our analysis, led by the authors and discussed within and beyond the research project was iterative, reflexive and, in as much as it could be, robust. Given the sheer quantity of data, as well as our sense that qualitative analysis software is most suited to the constant comparative method—which wasn’t appropriate to our study—we did not use software to help code or analyze the dataset. Rather, throughout this long process, we developed themes based on our study of the phenomenon, which we discussed among ourselves, with our colleagues and in reputed international academic gatherings, being careful that there was plenty of evidence illustrating each theme, though we were also mindful that a complex, global, and in many ways inscrutable phenomenon like Bitcoin is not easily reducible to themes or a theoretical model. In sum, constant triangulation of data from fora, blogs, social media and specialised news proved effective for our research group and extended community of interest to make sense of what was going on and to cope with the difficulties of having a moving target as a research focus.

Bitcoin as Klein Bottle Game

When one thinks of infrastructures one is unlikely to also think about games; infrastructures tend to be serious things—electricity networks, health information systems, ERP systems and the like—while games tend to be associated with children and trivial pursuits. However, our research shows that the information infrastructure that is Bitcoin is fundamentally infused by the principles of game design and game playing (Kane, 2005; Schell, 2008), which necessarily impacts how it is organized, governed and governable.

The first point to note is that Bitcoin is not just one game, but a multiplicity of games; games in—and on—games. For instance, it is a form of betting game, in that it is clear that many purchases of bitcoin are essentially speculative gambles that bitcoin’s value will increase into the future. Indeed, some—including the US Commodity Futures Trading Commission and the People’s Bank of China—see Bitcoin as a commodity or “digital asset” rather than a currency. And this is not a low-risk game as there is a real chance that the currency will totally collapse in value, not least because of the significant scalability issues that were recognized early in its development. A further feature of the gamble is that unlike bets on sporting events, which should not affect the result, bets on the value of a traded asset, whether this be a currency or a commodity, can be self-fulfilling since such bets can affect perceptions on which present and future values are based.

The game aspect of Bitcoin is also obvious when we consider bitcoin mining, which has two distinct betting dimensions. First, like others who hold or trade in bitcoins, miners are taking a gamble that bitcoin will continue to hold its value. However, there is also a second betting aspect peculiar to the practice of mining. Specifically, mining is *designed* as a competitive game as it is based on a series of “rounds” in which miners compete with one another to find a “proof-of-work,” with the winner obtaining a prize (a bitcoin).⁵ This is very much a game of chance, in that “proof-of-work”, which underpins the technology, is akin to throwing a pair of dice repeatedly until a highly unlikely series of numbers appears. From the miners’ perspective, Bitcoin is essentially a reward scheme for the computing power they provide to those who trade in or with bitcoin. The blockchain, then, is just the record of past rounds and continually lengthens as the game progresses, akin to an ever-growing chain of domino tiles.

⁵ Games are commonly used in cryptographic security proofs (Bellare and Rogaway, 2006). For example, in his original white paper, Nakamoto simulated an attack on his proposed system by a “dishonest” player, which he framed as a variation on the Gambler’s Ruin problem. His analysis indicated that his proposed Bitcoin protocol/game would incentivize a dishonest player to “play by the rules” (Nakamoto, 2008, p. 4).

In *The Art of Game Design*, Schell (2008) makes an important distinction between the game designer and the player, and this distinction also applies to Bitcoin (and perhaps to other infrastructures). Most obviously, Nakamoto was the game's primary designer and the original design is largely mapped out in his/her/their seminal white paper (Nakamoto, 2008) which now has mythical status within much of the Bitcoin community. Nakamoto also wrote the original code and released the first version of the game in 2009, and was also one of the earliest players, which is consistent with game design where game designers typically refine the game through repeated playing.

Bitcoin's game ethic draws on and echoes a wider ludic shift in the zeitgeist. The ludology literature is very much a recent phenomenon—notwithstanding the earlier contributions by Huizinga (1955) and Caillois (1961)—with almost all academic journals appearing since 2000: *Game Studies* (2001), *Game Developer* (2001), *Gaming Research & Review Journal* (2002), *Games & Culture* (2006), and *Eludamos: Journal for Computer Game Culture* (2007). The video game industry, which did not even exist 40 years ago, enjoyed estimated revenues of \$102 billion in 2015 and is now larger than the film industry, with 63% of US households having at least one person who plays video games regularly (at least 3 hours per week) (Entertainment Software Association, 2016). The principal web forum for board games, boardgamegeek.com, founded in 2000, now claims to have a database of over 76,000 games, and one million registered users. Similarly, there is a rapidly growing collection of books on games (Juul, 2005; Salen and Zimmerman, 2006; Schell, 2008; Järvinen, 2009; Elias et al., 2012; Woods, 2012) but there are very few books about games published before 2000.

It is therefore no surprise that the emergence of Bitcoin is concomitant to this wider interest in games. For instance, in his valuable study of the Bitcoin story, Popper posits that many of the youngsters who were attracted to Bitcoin in the early years (2009–2011) liked the card game *Magic* because it required “unexpected solutions to complex problems” (Popper, 2015, p. 94). One such *Magic* enthusiast and designer of online games was Jed McCaleb, who set up the infamous Mt. Gox bitcoin exchange in 2010. Indeed, McCaleb originally purchased the domain name mtgox.com because he wanted to create a website for users of *Magic: The Gathering* online service (mtgox is short for *Magic: The Gathering Online eXchange*), and he also used the domain name to advertise another online game that he designed, called *The Far Wild*. Moreover, the ethos of playing is also evident in his comment that he “created mtgox on a lark” and that it “has been interesting and fun to do” (McCaleb, 2011). Likewise, in

2012, Eric Voorhees, another prominent figure in the Bitcoin community, set up a gambling website that uses bitcoin, called SatoshiDice (after Satoshi Nakamoto), and which was a game of odds based on the same hash functions and mathematics as Bitcoin. He sold the site a year later for over \$12 million.

Board games like *Monopoly* are competitive, but a growing number of cooperative board games have become popular in recent years—coinciding with the spread of Bitcoin—such as *Pandemic* (2007), *Space Alert* (2009), *Sentinels of the Multiverse* (2011), *Freedom: The Underground Railroad* (2013).⁶ Bitcoin is a competitive game, in that the miners compete with one another, but it is also a *cooperative* game in that coalitions of players in pools are allowed, and the miners are also incentivized, through the game’s design, to work together to ensure that the “game” is not hijacked by a greedy attacker who may subvert the rules to their advantage and double-spend their money.

Indeed, the risk that the rules of the game will be subverted and changed—which is all but unthinkable since there is no access control—marks Bitcoin as different from other games like tennis, football and chess where everyone knows who is playing. Bitcoin is a game, but a particular and different type of game, and so we introduce the metaphor of the *Klein bottle* to capture these differences. In mathematics, a “Klein bottle” is a one-sided, non-orientable surface which a traveler can traverse but *will eventually be flipped upside down* on returning to the original starting point. It is a three-dimensional version of the better known Möbius strip and can be formed by joining two Möbius strips along their boundaries (see figure 1).



⁶ In August 2016, Wikipedia listed 742 cooperative video games (https://en.wikipedia.org/wiki/List_of_cooperative_video_games)

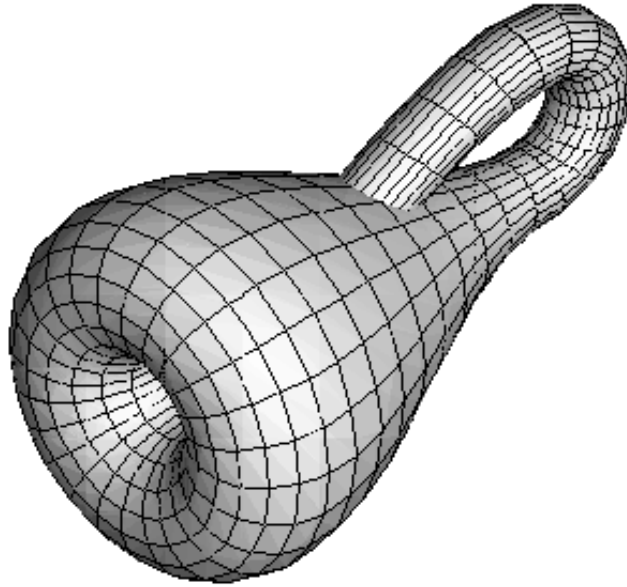


Figure 1. A Möbius strip (above) and a Klein bottle (bottom)

We find the metaphor of a Klein bottle more appropriate than a Möbius strip because while the latter is a surface with a boundary, *a Klein bottle has no boundary*: its inside is its outside. The metaphor is useful because it describes important aspects of Bitcoin that distinguish it from other types of games. Specifically, we see Bitcoin as a *Klein bottle game*, which has the following features.

1. The boundaries of a Klein bottle game are indecipherable.
2. Klein bottle games plug into other information infrastructures through “Klein portals”
3. Klein bottle games are digital versions of the carnivalesque
4. Paradoxical inversions are a feature of Klein bottle games, making them a space of difference, otherness and ambiguity

Indecipherable boundaries

There is a long discussion in the play literature on the idea that play is an “autotelic” activity, which is an activity engaged in solely for its own sake, with no meaning exterior to itself or ulterior motive outside of its own terms of reference. This idea goes back to Huizinga, who saw play as “an act apart”, separated by a “magic circle” from “ordinary life” (1955, p. 10, 13), a point picked up by Caillois (1961, p. 10) who saw games as “separate”. Similarly,

Schell (2008, p. 34) includes the idea of the game as a “closed formal system” within his 10 “game qualities”, while in the computer games literature Crawford (1984, p. 7) asserts that:

a game is a closed formal system that subjectively represents a subset of reality... By “closed” I mean that the game is complete and self-sufficient as a structure. The model world created by the game is internally complete; no reference need be made to agents outside of the game.

Others disagree, with Woods arguing that “board game systems are anything but closed” and that “a particular game can offer a vastly different experience depending upon the context in which it is played” (Woods, 2012, p. 6). Similarly, Juul argues that the boundaries between the game and real worlds are “fuzzy areas under constant negotiation” (Juul, 2005: 36). Here, the reasoning is that games are akin to fairy-tales in that they bring the player/reader into what Tolkien (1966/1983) describes as a “Second World” which is both consistent and rational, and which provides a unique and insightful perspective on the “Primary World”. Moreover, the primary and secondary worlds are not separate but mutually constitutive as understandings, principles and values interpenetrate between them. As Tolkien put it, the point of fairy stories, such as the frog princess story, “lies not in thinking frogs [as] possible mates, but in the necessity of keeping promises (even those with intolerable consequences) that, together with observing prohibitions, runs through all Fairyland” (Tolkien, 1966/1983, p. 152–3). Even the simplest games, like *Snakes & Ladders*, help frame and construct our understanding of concepts such as ambition, purpose, competition, failure, chance, turn-taking, beginnings and endings.

However, the Bitcoin story shows and requires a *third* way of thinking about games. Bitcoin is neither an autotelic activity—a closed formal system, separate from ordinary life—nor is it a moral tale, akin to a fantasy story, because both of these require a distinction between the game and “ordinary life” (or the secondary and primary worlds in Tolkien’s language). In the case of Bitcoin, we do not find such a distinction compelling since *it is premised on a clear delineation of boundaries*. What we see in the Bitcoin story is that putative boundaries are inevitably elusive and/or easily transgressed. For instance, initially there were very few people (or computers) involved in the Bitcoin network, and it was relatively easy to join the network and gain bitcoins, not least because it was designed to easily expand, through, for example, making the source code open. Now, miners drop in and out of the network and it is never clear or known who is in—or is not in—the mining game. At the time of writing, large mining pools are operating but their extent, location, make-up and resources are largely unknown. And, again largely by design, neither the extent of the network nor the identity nor

number of “players” is easily reckonable. Most obviously, Nakamoto’s identity was and is unknown to this day. Also, applications of all sorts keep springing up. Akin to chasing a leprechaun or the end of a rainbow, once one thinks one has identified a boundary the game changes. And without a boundary, it makes no sense to consider Bitcoin an autotelic system, nor does it make much sense to delineate the primary and secondary worlds. And this is why the metaphor of the Klein bottle is helpful: it has no boundary.

Klein Portals

Bitcoin’s boundaries are inherently difficult to identify partly because it is an infrastructure—albeit a nascent one—and infrastructures are axiomatically “sunk” into other structures, social arrangements and technologies. However, this “sinking” needs to be effected, which is not easily achievable. For instance, even though the notion of digital money had been discussed at least as far back as 1997, and Nakamoto has published his paper in August 2008, releasing the first version of the software in January 2009, it was May 2010 before bitcoins were used to purchase an actual “real world” item—specifically a pizza. What was effected in this watershed moment was what we will call a “*Klein Portal*” as it enabled the Bitcoin system (which we are characterizing as a Klein bottle game) to link with other infrastructures, namely those infrastructures that allow the production and distribution of pizzas. Of course the Bitcoin system already had material elements—hardware, desks, people, etc.—but what was different about the pizza purchase was that it effected an important feature of Bitcoin as infrastructure—i.e. it plugged Bitcoin into other infrastructures in a standard way (the sixth of Star and Ruhleder’s characteristics of infrastructures). Even before that celebrated pizza was purchased for 10,000 bitcoins (worth over €20million at 2017 valuation), a bitcoin currency exchange, Bitcoin Market, was already established (in February 2010) which enabled bitcoin to be traded for other currencies. While this was very small beer—and bitcoin currency exchange remains relatively small—it provided a link into a very large and robust network of currency exchange markets. Thus the Bitcoin Market constituted another Klein portal.

In linking a Klein bottle game with an existing information infrastructure, Klein Portals can become a site of advantage within the game or indeed the new practices that constitute the Portal may work to redefine the rules of the game. At the same time, and because a Klein bottle game is a dynamic game with no boundaries, Portals are also ready targets for subversion and sites of transgression. This happened with the main bitcoin exchange, Mt Gox, which was launched in 2010 and was, by 2013, handling 70% of all bitcoin transactions (Vigna, 2014). Mt. Gox was a Klein Portal in that it linked Bitcoin with other information

infrastructures, in this case the system of currency exchange markets. In 2011 Mt. Gox was silently hacked, causing the company to collapse 3 years later with the loss of some 850,000 bitcoins, worth more than \$450 million at the time. Another example of a Klein Portal is the infamous Silk Road marketplace, which was an online black market and the first modern darknet market. This website was launched in February 2011 by Ross Ulbricht, a.k.a Dread Pirate Roberts, relying on the Tor network and bitcoin to allow users to anonymously purchase goods, typically illegal drugs. Again, what we find is the creation of a Klein Portal linking a Klein bottle game (Bitcoin) with other information infrastructures allowing an illegal drug market. Similar to Mt. Gox, this Portal proved to be fragile, and in 2013 the Federal Bureau of Investigation arrested Ulbricht and shut down the website. Two years later, Ulbricht was convicted of drugs trafficking, money laundering, computer hacking and running a criminal enterprise, and he is also due to stand trial for procuring executions. In his telling of the story, Popper observed how Ulbricht segued from the world of video games into, allegedly, ordering executions: “It was easy to image that Ross, cut off from any real contact with other members of the community, except for Internet chats, began to see people as abstractions with no real life force—like characters in a video game. In this sort of world, the idea of killing these people could lose its visceral repugnance” (Popper, 2015, p. 227).

A Klein Portal links a Klein bottle game to other information infrastructures, though the nature of the Portal is reshaped as the practices on which it is based change. Moreover, the Klein Portal, as a set of practices, works to reshape the Klein bottle game itself, much like a tent is reshaped by driving tent-pegs—the metaphorical equivalent of Klein Portals—into the ground. Indeed, pegging a tent into the ground is a good metaphor for the way in which Klein Portals work to connect the “tent” that is a Klein bottle game with the “ground” (different infrastructures), or, from the other perspective, to see Bitcoin growing through leveraging other infrastructures. Infrastructures, such as the electricity network, are typically not Klein bottle games even though the concept might well have applied to them early in their evolution, as they are usually quite robust—if not immutable or indestructible—compared to the fragile Klein bottle game and its associated Klein Portals. Each Klein Portal works to reshape a Klein bottle game until eventually and cumulatively the latter may be reshaped to the point where it can no longer be considered a Klein bottle game. However, any such configuration is never permanent and, keeping with the metaphor, just as storms can pull a tent from its moorings, Klein Portals are always liable to fracture which can have catastrophic and dramatic consequences for the Klein bottle game.

Crypto-carnival

Klein bottles are spaces that exhibit juxtaposition, ambiguity, otherness, difference, transgression, and dissimulation. All of these are phenomena associated with the carnivalesque, which we identify as the fourth attribute of Klein bottle games. The carnival has traditionally been a site where established norms and structures are temporarily suspended, where conventional authority is contested, and where autonomy is favored over heteronomy (Bakhtin, 1968/1984). Bitcoin is similar in that it is very much an explicit attempt to escape the existing social order where states and banks are dominant players, a theme we find expressed in a recent history of Bitcoin: *The Age of Cryptocurrency: How Bitcoin and Digital Money is Challenging the Global Economic Order* (Vigna and Casey, 2015). In the carnival, things are often not what they appear to be; in place of truth and transparency, we find make-believe, pretense and dissimulation, epitomized in the carnival's iconic image, the mask. Likewise in Bitcoin. Most obviously, the cryptocurrency emerged out of the cypherpunk movement which was dedicated to building anonymous systems on the Internet, including anonymous digital money (Lopp, 2016). The cypherpunks had an almost paranoid obsession with privacy and put huge effort into developing complex cryptographic systems that worked to create what are essentially “digital masks”. Consistent with this, the original and seminal Bitcoin white paper was written by a mysterious character or characters, Satoshi Nakamoto, whose identity remains unknown to this day. More broadly, the effect of the blockchain technology means that the identity of actors is unusually difficult to pin down. Cryptographic code, embedded in algorithms, works to coordinate and act across a distributed network of computers of unknown size and location, and where identifiable actors and identities are not readily constituted or identifiable. Thus, what Bitcoin has created is a phantasmatic world where there is action without actors, a ghostly world quite in keeping with the carnivalesque.

In both the carnival and in Bitcoin, we find that this transgression of norms easily transgresses into illegal activity. In the carnival we find prostitution, cheating, stealing, fighting and gaming, while the best known instances of illegality in Bitcoin are the cases of Mt. Gox and Silk Road, while Liberty Reserve, which had over \$8 billion of transactions, was another significant case of transgression involving digital money. Not surprisingly, authority has always found it difficult to deal with the carnivalesque. Bakhtin (1968/1984, p. 109) suggests that the inversions of the carnival—such as a commoner acting as a king—are best seen as attempts by the lower orders to subvert and challenge the dominant social

hierarchy. Others have claimed that it is precisely because carnivals and fairs were sites of (potential) revolt that they were suppressed, especially in the nineteenth century (see Ó Maitiú (1995) for a description of the State and Church suppression of Donnybrook Fair), while there is also a view that the carnival was a location where social protest was *licensed* and thus controlled (Sales, 1983). In their study of the carnival in the nineteenth century, Stallybrass and White argue that the carnival provided the emerging bourgeoisie with a depiction of a profane Other, and encoded “all that which the proper bourgeois must strive *not to be* in order to preserve a stable and ‘correct’ sense of self” (Stallybrass and White, 1986, p. 178). Hence, the carnival was both contained and sanctioned to ensure that this “sense of self” was maintained. We can detect a similar ambiguity with respect to how authority has responded to what might be depicted as a digital version of the carnivalesque: Bitcoin. Speaking at the BitFin conference in 2014, the Irish Central Bank’s Director of Markets Supervision, Gareth Murphy, urged the Bitcoin industry to “work actively to address the concerns of financial authorities rather than ‘playing cat and mouse’ and eventually, and inevitably, being drawn into the regulatory net” (Murphy, 2014). Yet, as of May 2017, the Irish Central Bank had made no official comment or taken any action on Bitcoin. More broadly, The Law Library of Congress, Global Research Center, in a 2014 survey of the regulation of Bitcoin in different jurisdictions, found that “the debate over how to deal with this new virtual currency is still in its infancy”. Two years later, the authorities continue to be tentative about Bitcoin, as illustrated by the title of de Filippi’s (2016) article, *We must regulate Bitcoin. Problem is, we don’t understand it*. At the same time, the elements of a regulatory structure are being put in place. In 2013, the New York State Department of Financial Services announced an interest in regulating it, as it subpoenaed the major Bitcoin players seeking information on their operations. Two years later, the same regulator introduced BitLicense, a business license for virtual currency activities, though this was soon challenged in the Supreme Court of the State of New York. Other regulatory authorities have also been working to understand how best to engage with the phenomena, with the European Central Bank publishing reports on “virtual currency schemes” in 2012 and 2015 (European Central Bank, 2012; 2015), while the Bank of England is considering issuing its own digital currency (Danezis and Meiklejohn, 2015; Haldane, 2015; Small, 2016).

In large part, the authorities have maintained a watching brief on Bitcoin, only engaging with the phenomenon when the transgressions are of significant size, as happened with Mt. Gox and Silk Road. Such tentativeness is understandable for two reasons. First, Bitcoin’s impact

on the economy is relatively small, and authorities have enough to be bothered about. Second, cryptocurrencies are difficult to understand, so effects of regulatory actions can be unpredictable. For instance, it is not clear if Bitcoin is a currency, a collective, a commodity, or a security. Its legal status is equally unclear: it might be a “chose in action” (i.e., a right to sue for possession or recovery of personal property, damages, or a debt) or a “chose in possession” (i.e. something in one’s actual possession) or it may be a “tertium quids” (a third something), a completely new class of private property (Bayern, 2014). If it is, then it only reinforces Bakhtin’s (1968/1984) point that the carnival is a special, *creative* life-form.

Thus, Bitcoin is what we might call a “crypto-carnival”. As such, it exhibits, but in a new form, the long-standing tension between the carnivalesque and authority, a tension that Tim May well anticipated when he wrote the crypto-anarchist manifesto in 1988:

The State will of course try to slow or halt the spread of this technology, citing national security concerns, use of the technology by drug dealers and tax evaders, and fears of societal disintegration. Many of these concerns will be valid; crypto anarchy will allow national secrets to be traded freely and will allow illicit and stolen materials to be traded. An anonymous computerized market will even make possible abhorrent markets for assassinations and extortion. Various criminal and foreign elements will be active users of CryptoNet. But this will not halt the spread of crypto anarchy. (May, 1988)

Ironic inversion/subversion

If one travels on a straight line on the surface of a Klein bottle one can eventually return to the original starting point but be *flipped upside down*. This is a curious feature of the Klein bottle and one that we also see present in the Klein bottle game that is Bitcoin. Bitcoin emerged out of the cypherpunk movement which first surfaced in the late 1980s and early 1990s, led by people like Tim May who sought to use technology, especially cryptography, to advance a political ideology centered on protecting privacy, countering mass surveillance, promoting individual liberty and freedom of expression, and fostering alternative financial and economic systems (May, 1988; 1994). As earlier as 1988, May (1988) and others were arguing that the power of the state, and to a lesser extent corporations, needed to be undermined:

Just as the technology of printing altered and reduced the power of medieval guilds and the social power structure, so too will cryptologic methods fundamentally alter the nature of corporations and of government interference in economic transactions. Combined with emerging information markets, crypto anarchy will create a liquid market for any and all material which can be put into words and pictures.

Some years later, the theme continued:

Some of us believe various forms of strong cryptography will cause the power of the state to decline, perhaps even collapse fairly abruptly. We believe the expansion into

cyberspace, with secure communications, digital money, anonymity and pseudonymity, and other crypto-mediated interactions, will profoundly change the nature of economies and social interactions (May, 1994, §2.13.1).

If May was talking abstractly about digital money, other cypherpunks were working to put the ideas into practice. For instance, Hal Finney, an active cypherpunk since the early 1990s, was instrumental in the early development of Bitcoin, having previously worked with Nick Szabo on an early form of digital money in the late 1990s. He subsequently collaborated with Nakamoto, receiving the first bitcoin transaction from the latter in 2009. It is clear that Nakamoto also shared the cypherpunks' libertarian distrust of "third parties", be they governments or large corporations, and this distrust continues to be widely shared and articulated within the Bitcoin community. However, it is ironic that some 28 years after May predicted that "cryptologic methods [will] fundamentally alter the nature of corporations and of government interference in economic transactions" (May, 1988) it is still just a prediction, and indeed it is arguable that governments and large corporations are stronger than ever online.

While governments have been tentative in seeking to regulate Bitcoin, the apparatus of the state has been quick to act when there is evidence of major fraud, as we have seen in the prosecution of individuals behind Mt. Gox, Silk Road, Liberty Reserve and GoldAge. For their part, larger corporations, while they were initially not engaged with Bitcoin, most likely because it was still relatively small, are now very active in appropriating and reworking the blockchain technology for their own benefit. For instance in 2016, Deloitte created a Blockchain Lab and announced five partnerships with blockchain startups (del Castillo, 2016a); PwC partnered with two blockchain companies (del Castillo, 2016b); while Ernst & Young also invested in the space (Reed, 2016). The major challenge these businesses are addressing is how to use the blockchain technology and still meet anti-money-laundering (AML), know-your-customer (KYC) and Countering the Financing of Terrorism (CFT) regulatory and legislative requirements. If they achieve this, then the technology will radically subvert Nakamoto's original plan, which was to develop a system that ensured non-mediated transactions. Moreover, the large corporates will almost certainly seek to use this to exclude new entrants from the financial services market, which will allow them to cement their dominant position in the market, which is again quite the opposite to what Nakamoto originally intended.

Another example of this ironic inversion is that while Nakamoto designed the Bitcoin protocol as a *decentralised* system to exclude powerful third parties, what has actually

happened is that mining has become *centralised* in very large mining pools. One indication of this is that by June 2016 just four mining pools controlled 69% of the mining market (<https://blockchain.info/pools>). The idea of the Klein bottle—where traversing the surface eventually flips one upside down—captures this paradox. What starts as an anti-statist and anti-corporation ideology works to support rather than undermine large organizations; a protocol that is designed to foster decentralization becomes centralized; while a technology developed by anti-establishment anarchists becomes appropriated by the Big Four accounting firms and large corporates.

Final Remarks

We began this paper by identifying two broad conceptualisations of information infrastructures: one that sees them as manageable assets amenable to “top-down” design and control, and another that advocates a “bottom-up” approach. Constantinides and Barrett (2015), in their study of the development of an integrated electronic healthcare record system in Greece, seek to address this “top-down/bottom-up” debate by advocating a “polycentric” form of governance, featuring multiple governing units at different scales, with “the nesting of governance into a broader network of institutions, in which governance is broken down into a series of layers” (p. 52). How does the Bitcoin case contribute to this discussion? One important point is that “nesting” requires a hierarchical structure, with layers between a top and a bottom, and such a structure is not identifiable in Bitcoin. Instead, the structure of Bitcoin seems more akin to Engeström’s (2006) notion of mycorrhizae-like formations. A mycorrhiza is a symbiotic association between a fungus and the roots or rhizoids of a plant, and is effectively invisible and difficult, if not impossible, to bound and close, though it is not indefinite. For Engeström, the Linux community has these mycorrhizae-like attributes, and indeed we see a good deal of similarity between the Bitcoin and Linux communities. While the concept of mycorrhizae is helpful, we prefer the notion of a Klein bottle game as it (a) foregrounds the ludic nature of the phenomenon; (b) captures the difficult-to-imagine idea of a boundary-less object; (c) incorporates the idea of action leading to inversion; and (d) it resonates with the concept of the crypto-carnavalesque.

On this last point, there is long-standing link between the carnival and the market, as traditionally both were co-located in time and place. In the case of Bitcoin, the market is central in three respects: first, the Bitcoin infrastructure creates money (bitcoin) which is intrinsic to almost all markets; second, it creates a market for a particular form of money, bitcoin, as well as markets for all sorts of derivative products; and third, it is a market-making

technology, in so far as the blockchain technology is widely seen as a disruptive technology that will create new markets and destabilize industries (World Economic Forum, 2016).

Bitcoin is a quite distinctive phenomenon—it may very well be *sui generis*—and so one should be careful in extending this analysis to other instances of information infrastructures. For instance, even though Bitcoin and Wikipedia both involve a community of actors and a shared infrastructure, they embody very different models of governing digital social production. If Wikipedia is a “a community of dissensus” that facilitates and requires ongoing debate (Jemielniak, 2014, p. 84), Bitcoin is better understood as a manifestation of faceless consent, with the protocol ensuring that once a miner wins the competitive puzzle, and this is collectively notarized by the other miners, then the relevant block is added to the blockchain, which is then immutable. This makes the blockchain a most interesting phenomenon. In some ways, the blockchain is an example of the well-known concept of “boundary object”, which is something that is “both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites” (Star and Griesemer, 1989, p. 393). At the same time, the sophisticated cryptographic protocol ensures that the blockchain is immutable, which makes it quite distinctive as an object. It is *designed to disallow* multiple interpretations, and in that sense it is quite the opposite to a boundary object. We might say that it is a boundary object *and a boundaryless* object—as is a Klein bottle. This apparent paradox is in accord with the Klein bottle shape, in that moving on a Klein bottle literally turns things upside down.

Bitcoin is also distinctive in that, in contrast to almost all other information infrastructures, neither a government, public body nor a large corporation were involved in its development. Unlike the 41 cases of information infrastructure listed by Henfridsson and Bygstad (2013), Bitcoin was developed by a loose network of individuals, who were not only not acting on behalf of a government, public body or large corporation, but indeed were involved in cryptocurrencies to undermine what they saw as the excessive power of these entities. And while Constantinides and Barrett (2015) could identify six ideological positions in their study of the development of a health information infrastructure in Greece—based around different understandings of whether an infrastructure should be a public or a private good—it is clear that a single libertarian ideology underpinned and was hegemonic in the development of Bitcoin.

This libertarian ideology was articulated by a relatively homogenous group, notwithstanding its open and dispersed structure. Here, Lustig and Nardi’s (2015) study of Bitcoin users is

revealing. Of the 510 responses they received to a survey they posted on popular Bitcoin fora, 51% were American, 96% were male, 74% were atheist or agnostic, 60% were libertarian, and 50% were between the ages of 15 and 34. Women are also singularly absent from Popper's (2015) comprehensive history of the Bitcoin story: only five appear in the list of 126 individuals indexed in his book, and none of these played a significant part in the narrative.

Information infrastructures are important and can have far-reaching and often unintended consequences. In this paper we have analysed an iconic global monetary infrastructure that originated in libertarian values, is maintained by a game ethic, and now moves billions of dollars across jurisdictions. We have introduced the concepts of the Klein bottle game and the crypto-carnavalesque as ways of understanding this distinctive and profoundly interesting phenomenon. Even if Bitcoin does not survive, it seems most likely that money will take on new forms in the digital society of the future, creating new challenges for how we live in and make sense of that world.

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